FRICTION

What is FRICTION

If two bodies are in contact with one another, the force exerted between them at their point of contact opposing the motion of one body to the another body is called friction and the force exterted is known as force of friction.

The friction is a force distribution at the surface of contact and acts tangential to the surface of contact.

Importance of FRICTION

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The friction plays a very important role in many engineering applications. Friction is quite undesirable in many engineering applications, in which it would cause loss of power, wearing out of parts and huge economic losses, such as

i) Bearings and gears
ii) Flow of fluids in pipes
iii) Power screw.

In many other engineering applications, friction is quite necessary as their working is very much dependent on friction. Such as

i) Brakes and clutches ii) Belt and rope drive.

Types of FRICTION

a) DRY FRICTION

b) FLUID FRICTION

c) STATIC FRICTION

d) DYNAMIC FRICTION OR KINETIC FRICTION

DRY FRICTION OR COULOMB'S FRICTION

This type of friction is encountered between the surfaces of two rigid bodies when there exists a sliding motion or there is a tendency of motion in the absence of any oil or lubrication in between. The dry friction is present even if there is no motion, under the condition of impending motion and when there is motion. It is also called Coulomb's friction, named after the scientist Coulomb who had carried out several experiments in this domain to realise the theory in its present form.

Laws of Friction

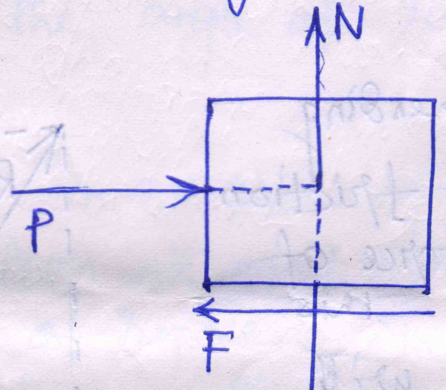
Coulomb presented summarised outcome of a large number of experiments related to dry friction that become famous as Coulombs Laws of friction or simply Laws of friction, which are as following

a) The total force of friction that can be developed is independent of magnitude of area of contact.

b) The total force of friction that can be developed is proportional to the normal reaction transmitted across the surface of contact.

c) For low relative velocities of sliding, the total force of friction is practically independent of velocity.

~~conclusion of~~



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Conclusion of Law (b) can be mathematically represent as

$F \propto N$

or, $\boxed{F = \mu N}$

where
F => Frictional force
N => Normal reaction
P => applied force
W => self Weight

Here the constant of proportionality (μ) defined as co-efficient of friction. In static condition it is expressed as μ_s and for dynamic condition μ_k. For same set of contact surfaces, it has been observed that μ_k is almost 75% of μ_s.

(Friction force better to be shown with half arrow as it is a short of shear force)

Angle of Friction

At the time of impending motion, the force of friction F is defined as force of limiting friction. In this condition the Fig-a will illustrate as how the resultant of normal reaction N and force of limiting friction F

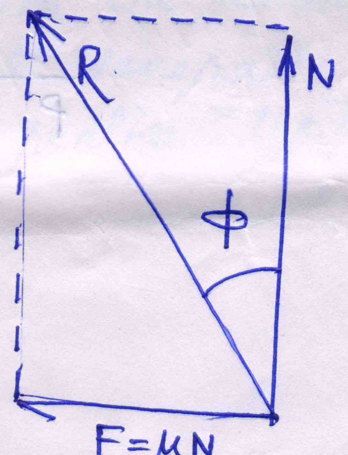


Fig-a

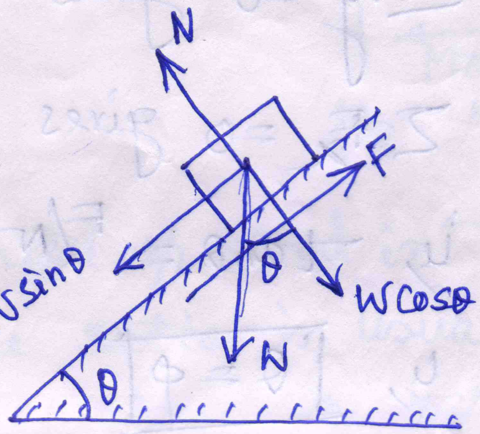
can be obtained. If the resultant force R makes an angle (independent of magnitude of are of contact) ϕ with normal reaction N

$$\boxed{\tan\phi = \frac{\mu N}{N} = \mu}$$

Here this angle ϕ is defined as limiting angle of friction or simply the angle of friction.

Angle of Repose

Let us consider a block of weight W resting on an inclined plane which makes an angle θ with the horizontal plane. When θ is small the block will rest on the plane. If θ is increased gradually a stage is reached at which the block starts sliding. This angle is called the angle of repose betn two contact surface.



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Thus the maxm inclination of the plane on which a body, free from external forces, can repose (sleep) is called Angle of repose. The block is in equilibrium under the action of the following forces,

(a) Weight of the block W
(b) Normal force N
(c) Frictional Force F $(=\mu N)$

In the limiting condition when the block is about to slide down the inclined plane, the frictional force must act up the plane for equilibrium.

$$\Sigma F_y = 0 \text{ gives } N = W\cos\theta$$

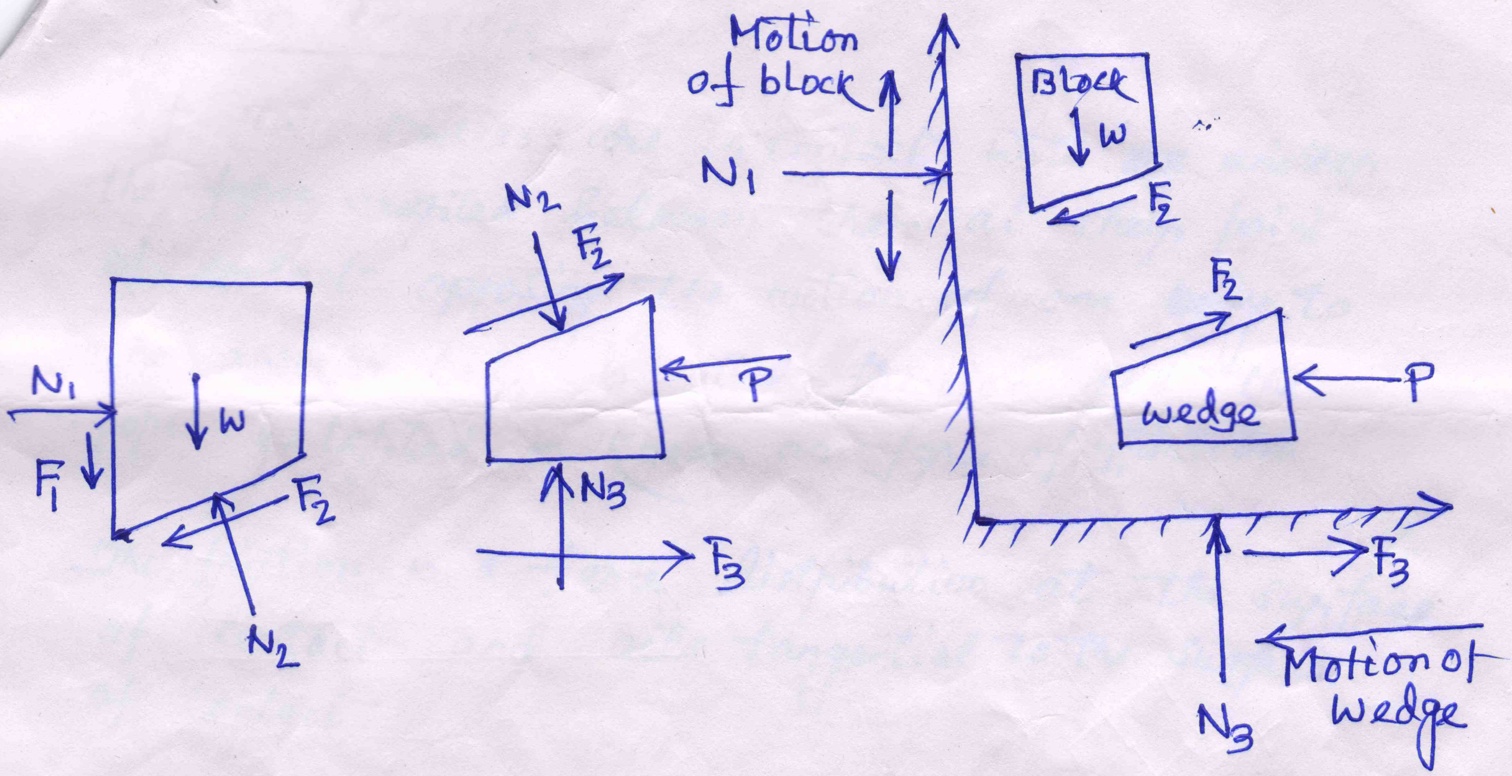
$$\Sigma F_x = 0 \text{ gives } F = W\sin\theta$$

i.e, $\tan\theta = F/N = \mu = \tan\phi$

i.e, $\boxed{\theta = \phi}$

The value of angle of repose is the same as the value of limiting angle of friction.

Wedge Friction



A wedge is a piece of metal or wood in the shape of a prism whose section is usually triangular or trapezoidal. Wedges are very simple machines, those are most usefull in lifting or moving heavy loads. When lifting loads, the wedge is placed below the load and a horizontal force P is applied. The wedge moves towards left and the load moves upward.

$\mu_1 \Rightarrow$ co-efficient of friction betn wall and the block
$\mu_2 \Rightarrow$ " " " " block and wedge
$\mu_3 \Rightarrow$ " " " " wedge and floor
$W \Rightarrow$ weight of the wedge.

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Numerical Example (Friction)

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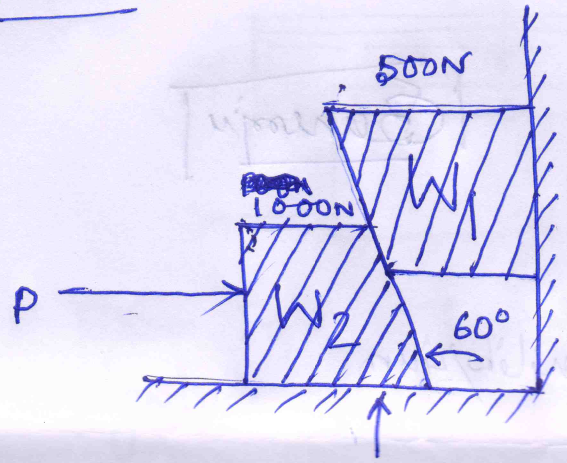
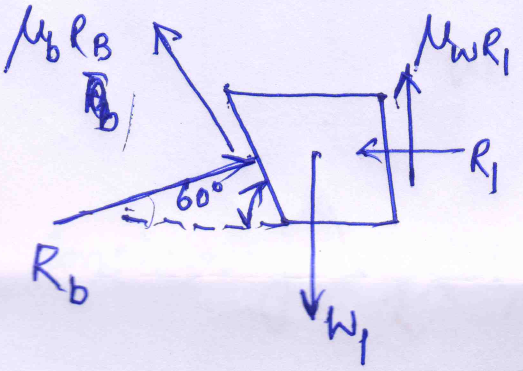
Prob-1



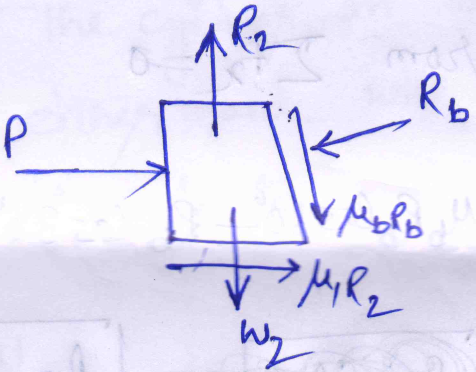
Co-efficient of friction (μ_f) at floor is 0.25, co-efficient of friction at wall (μ_w) = 0.30 coefficient of friction bet^n blocks (μ_b) = 0.20 Find min^m P to hold the system in equilibrium.

Sol^n

FBD of W_1



FBD of W_2



Now From FBD of block W_1

$$\Sigma F_x = R_b \cos 30^\circ - \mu_b R_b \cos 60^\circ - R_1$$

∴ $R_b \cos 30^\circ - \mu_b R_b \cos 60^\circ - R_1 = 0$

ie, $\boxed{R_1 = 0.766 R_b}$ —— (1)

again $\Sigma F_y = \mu_b R_b \sin 60^\circ + \mu_w R_1 + R_B \sin 30^\circ - W_1$

ie, $\mu_b R_b \sin 60^\circ + \mu_w R_1 + R_B \sin 30^\circ - W_1 = 0$

or, $\boxed{0.637 R_b + 0.3 R_1 = 500}$ —— (2)

Now from equ^n (1) and (2)

$\boxed{R_b = 553.8\ N}$

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From FBD of Block W_2

∴ From the condition of equilibrium

$\sum F_x = 0$ and $\sum F_y = 0$

Now $\sum F_y = R_2 - R_b \sin 30° - \mu_b R_b \sin 60° - W_2 = 0$

or, $\boxed{R_2 = 1372.7\ N}$

again from $\sum F_x = 0$

$P + \mu_f R_2 + \mu_b R_b \cos 60° - R_b \cos 30° = 0$

i.e., $\boxed{P = 80.8\ N}$

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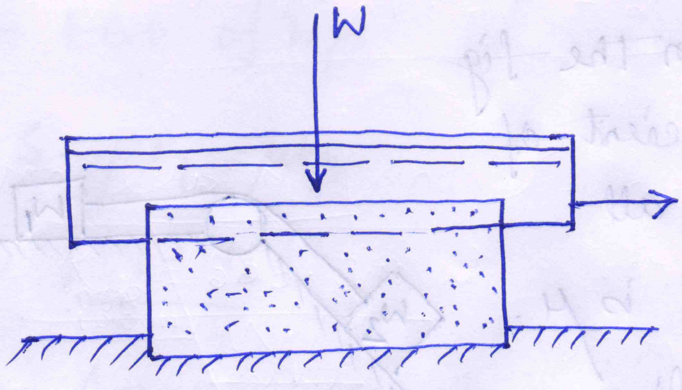
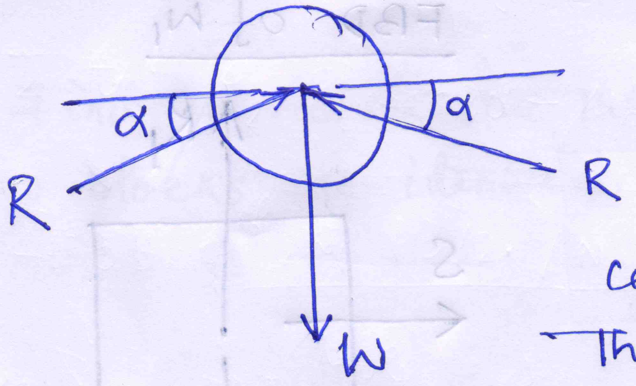


~~Prom~~ For the problem in the above fig, find magnitude of P causing motion of cylinder to impend.

Solⁿ



From symmetry we can say that the reaction coming from notch on the cyliner on ~~coating~~ either side will be equal.

Considering equilibrium of cylinder.

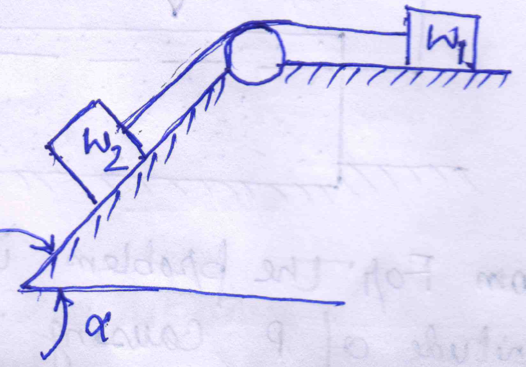
$$2R\sin\alpha = W$$

$$R = \frac{W}{2\sin\alpha}$$

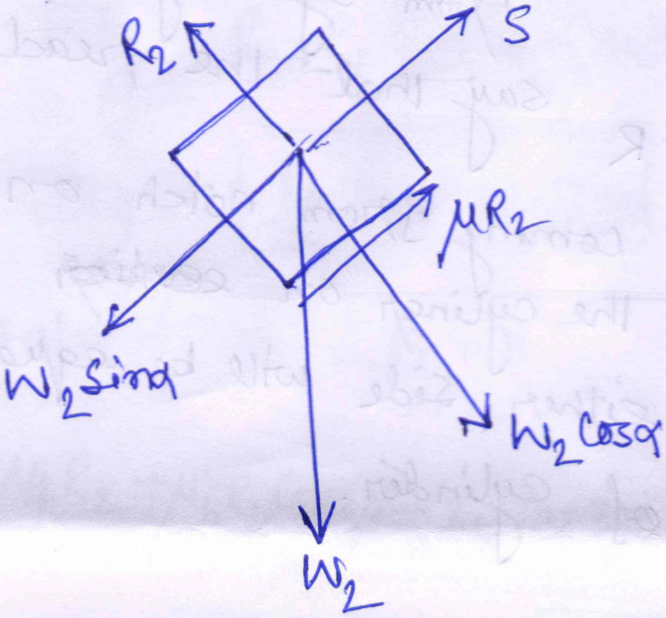
As the horizontal friction force induced on ~~s~~ inside ~~sep~~ surface of notch be $F = \mu R$ on either side

$$P = 2F = 2\mu R = \frac{\mu W}{\sin\alpha}$$

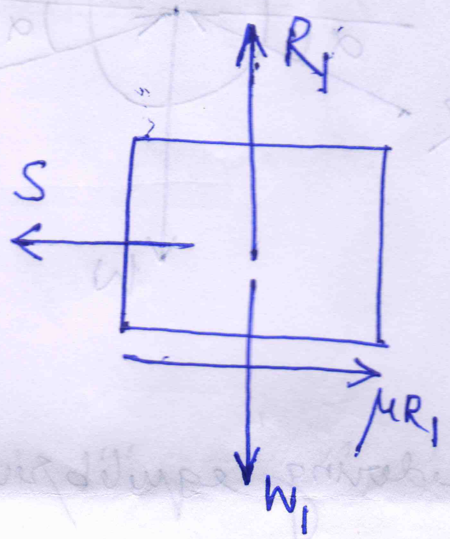
3. For the problem in the fig $W_1 = W_2$ and co-efficient of static friction for all contiguous surfaces is μ. Find α for impending motion. Consider pulley frictionless.



Solⁿ FBD of W_2



FBD of W_1



Now from FBD of W_2

$$R_2 = W_2 \cos\alpha$$

and $\quad S + \mu R_2 - W_2 \sin\alpha = 0$

ie, $\quad S = W_2 \sin\alpha - \mu R_2$

$$= W_2 \sin\alpha - \mu W_2 \cos\alpha$$

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From FBD of W_1

$$S = \mu R_1 = \mu W_1$$

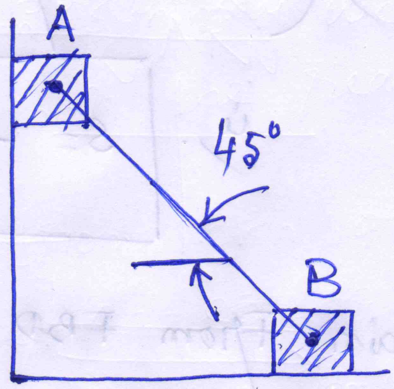
i.e., $\boxed{W_1 = W_2}$

$$\mu = (\sin\alpha - \mu\cos\alpha)$$

$$\boxed{\mu = \tan(\alpha/2)}$$

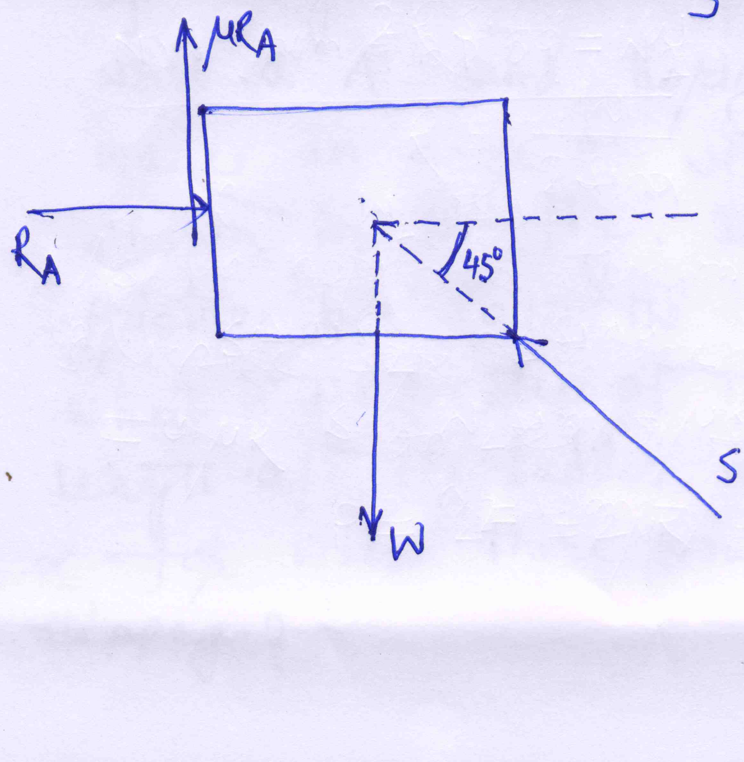
4

Find μ where the the two blocks are identical.

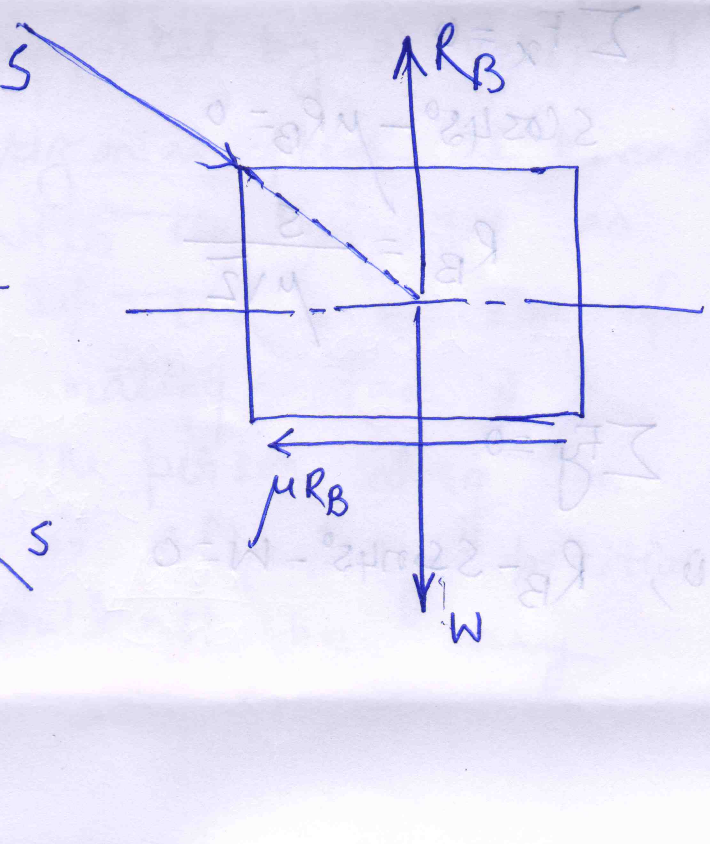


Solⁿ

FBD of block A



FBD of block B



Now From FBD of block A considering equilibrium

$\sum F_x = 0$

ie, $R_A = S\cos 45^\circ$

again $\sum F_y = 0$

ie, $(S\sin 45^\circ + \mu R_A - W) = 0$

ie, $\boxed{S = \frac{\sqrt{2}}{1+\mu}W}$ ——— (1)

again From FBD of block B considering equilibrium

$\sum F_x = 0$

$S\cos 45^\circ - \mu R_B = 0$

$R_B = \frac{S}{\mu\sqrt{2}}$

$\sum F_y = 0$

ie, $R_B - S\sin 45^\circ - W = 0$

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ie, $\frac{S}{\mu\sqrt{2}} - \frac{S}{\sqrt{2}} - W = 0$

$$\boxed{S = \frac{W \cdot \mu \cdot \sqrt{2}}{1-\mu}} \text{ ——— } (2)$$

Equating (1) and (2)

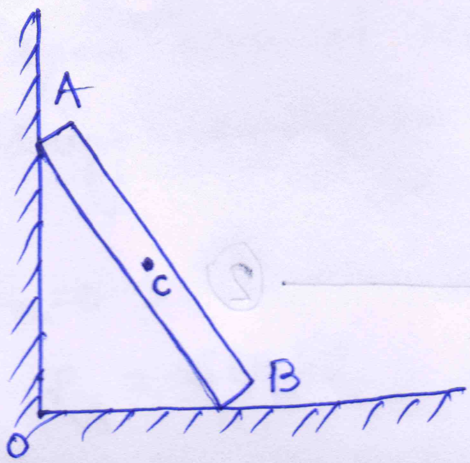
$$\frac{1}{1+\mu} = \frac{\mu}{1-\mu}$$

OR, $\mu^2 + 2\mu - 1 = 0$

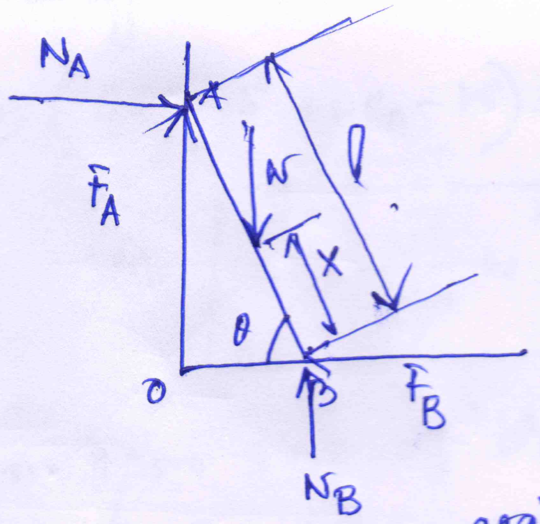
ie, $\boxed{\mu = 0.414}$

5. A ladder AB of length l carries a person of weight W and supported by a vertical wall at A and horizontal floor at B and makes an angle θ with the horizontal as shown in the fig. If the co-efficient of friction bet^n all the mating surface is μ, what is the location of the person along the length of the ladder as defined by position x for which there would not be any slippage?

p-8



Sol^n



considering the equilibrium of the ladder

$\sum F_x = 0$

ie, $N_A - F_B = 0$

ie, $\boxed{N_A = F_B}$ —— (1)

again $\sum F_y = 0$

$N_B - W + F_A = 0$

ie, $\boxed{N_B = W - F_A = W - \mu N_A}$ ← (2)

$\sum M_B = 0$

ie, $W \times x\cos\theta = N_A + l\sin\theta + \mu N_A \cos\theta = N_A l [\sin\theta + \mu \cos\theta)$

—— (3)

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Now comparing equ^n ① and ②

$$N_A = \frac{\mu W}{1+\mu^2}$$

Replacing N_A in equ^n ③

$$W \times x \cos\theta = \frac{\mu W}{1+\mu^2}\, l\left[\sin\theta + \mu\cos\theta\right]$$

$$\text{or, } (x\cos\theta)(1+\mu^2) = l\left[\mu\sin\theta + \mu^2\cos\theta\right]$$

$$\text{or, } x\cos\theta\,(1+\tan^2\phi) = l\left[\tan\phi\sin\theta + \tan^2\phi\cos\theta\right]$$

[$\because \mu = \tan\phi$ where ϕ is the angle of friction]

$$\text{or, } x\cos\theta = l\sin\phi\left[\cos\phi\sin\theta + \sin\phi\cos\theta\right]$$

$$\text{or, } x\cos\theta = l\sin\phi\sin(\theta+\phi)$$

$$\because \cos\phi\cos(\theta+\phi) + \sin\phi\sin(\theta+\phi) = \cos\left[\phi-(\theta+\phi)\right]$$

$$\therefore \sin\phi\sin(\theta+\phi) = \cos\theta - \cos\phi\cos(\theta+\phi)$$

$$\therefore x\cos\theta = l\sin\phi\sin(\theta+\phi) = l\left[\cos\theta - \cos\phi\cos(\theta+\phi)\right]$$

Thus $x = \frac{l}{\cos\theta}\left[\cos\theta - \cos\phi\cos(\theta+\phi)\right]$